Abstract—People with disabilities face many issues when it comes to parking in urban areas which include the limited availability of spaces allocated for their use and the unauthorised usage of such spaces. This paper presents DisAssist which is a system designed and developed based on the principles brought forward by the Internet of Things and Smart Cities initiatives; it integrates sensors and smart phones along with wireless and mobile communications to provide for better utilisation and management of parking spaces allocated for use by people with disabilities. Through the use of DisAssist, people with disabilities may obtain real-time availability of parking slots in an area of interest, reserve a slot and authenticate themselves when parking assisting the authorities with usage monitoring for law enforcement as well as capacity planning purposes. Entitlement verification is possible through a multitude of ways enabling users to embrace technology at the level and format they wish.

Keywords- Internet of Things, smart cities, disabled parking space, parking reservation, parking monitoring

I. INTRODUCTION

During the last couple of decades, urban cities have seen unprecedented expansion due to the growth of population and business activities. One of the challenges of a modern urban environment is to be agile and friendly towards the needs of people with disabilities. One service towards this direction is the provision of convenient parking access to various locations so that people with disabilities can carry out their activities with ease.

In this context, let us imagine a scenario where it is rush hour and city centre traffic is at its peak. As a result, almost all parking spaces are already occupied. A person with a physical disability is trying to access the city centre, but unfortunately he/she (or a carer) has to drive in circles to find an empty disabled parking slot, which is obviously a significant inconvenience. Moreover, due to the high demand for parking spaces, there are some drivers who occupy disabled parking slots without having the right to do so and even, in some cases, there are violators who have fake documents displayed on their windscreen. It is clear, that even though the current infrastructure provides accessibility to people with disabilities, it lacks the ability to comprehensively manage the parking slots allocated for their exclusive use and to distinguish between legitimate users and opportunistic offenders.

The proliferation of Internet of Things (IoT) technologies and their increasing utilisation within Smart City initiatives [1], can lead to significant contributions and technological advances towards a more inclusive society through accessibility to public services and from our perspective, urban parking infrastructures.

To this extent, in this paper we propose a smart parking management system called DisAssist. The main aim of DisAssist is to enhance the parking experience from the perspective of people with disabilities. This is achieved by providing solutions for some of the issues faced today regarding the use of parking spaces allocated for their exclusive use. Note that we do not make any sort of distinction or categorization among people with disabilities; the activities mentioned hereafter (i.e. driving or interactions with the system) may well be carried out by a carer on behalf of the person with the disability who may be the driver of the vehicle, or a passenger. By introducing automated and semi-automated entitlement verification mechanisms and integrating them with parking monitoring technologies, DisAssist aims to improve the quality of life of many citizens.

Within the DisAssist platform, we take advantage of the capabilities of modern mobile devices which allow some users to access real-time parking availability information obtained via Machine-to-Machine (M2M) communications. Going a step further, the ability to reserve a space in advance, will further alleviate drivers from the often long search for a vacant space contributing towards a more intelligent transportation environment. Moreover, the quick and on-the-spot verification of user entitlement will allow organizations responsible for monitoring the designated parking lots to operate much more efficiently. Note that in order to allow the system to be adopted by as many potential users as possible, there is a purposeful variety of levels of engagement (ranging from a smart phone application to simple text messaging) in order to cater for people with varying technological skills.

The rest of this paper is organized as follows: in Section II we provide information on outstanding issues as well as the technologies that will be utilized in the
proposed system whose architecture and implementation are described in Sections III and IV respectively. Finally, in Section V we provide our conclusions.

II. MOTIVATION AND TECHNOLOGICAL BACKGROUND

In this section we first provide an overview of today’s parking infrastructures from a management perspective and then focus on the motivation of our work which concerns the seamless provision of parking facilities for people with disabilities.

A. Parking management

 Millions of drivers all over the world have to use public car parks on a daily basis. There is a large variety of vehicle parking infrastructures available to the public and these belong to two major categories: ‘on-street’ which refers to the parking bays found on the roadside and ‘off-street’ which comprises of different categories of parking lots ranging from single level areas to large multi-storey car parks.

The rise in urban population increases the demand for parking infrastructures not only in terms of spaces but also associated services. Parking operators try to adopt methodologies for improving their revenue while offering advanced facilities to their customers; parking space monitoring and advance parking reservation are currently deemed as highly valuable features [2].

1) Parking availability monitoring

Nowadays, monitoring of parking spaces is not only required for checking for fee payments and usage entitlement but also for calculating availability and reporting such information to drivers searching for vacant spaces. The large variety in vehicle parking infrastructures implies that there is no single generic and also cost effective approach for monitoring parking spaces. Obviously, there are various access control and payment mechanisms which may remove the need for monitoring (e.g. in gate-controlled parking lots) and also provide availability data. However, herein, we focus on monitoring individual spaces which are often found on the roadside. As such, the predominant methodology for monitoring such parking spaces is still based upon physical observation; unfortunately, this traditional method does not readily provide any form of availability data.

Parking availability is one of the most promising applications of IoT technologies as it attempts to tackle an important issue faced by millions of drivers around the world. To facilitate the real-time availability of such information, an interesting methodology was proposed in [3]. We also see various sensor-based solutions (e.g. magnetic, optical, ultrasonic) being deployed usually as part of smart city infrastructures; once a vehicle is detected, information is wirelessly transmitted to a gateway which aggregates the data and relays it to a server. Information is then made available to drivers through various means. Crowdsourcing has also been suggested as a method of gathering parking availability data [4]; through a special application users report their intention to vacate the parking space their vehicle is currently occupying.

2) Parking space reservation

The dissemination of parking availability information can enable a service that many drivers find useful especially in peak hours: parking reservation. The concept of parking reservation was studied by various researchers. Again, by considering the variety in parking lots, we see that parking reservation can be implemented relatively easily in controlled areas (e.g. gate-controlled parking lots) [5] that can theoretically enforce reservations and hence guarantee the availability of the reserved space. On the other hand, in open spaces (e.g. on-street parking bays) actions such as user (i.e. driver or vehicle) verification and reservation enforcement, are somewhat more difficult to accomplish [6]. Other issues identified relate to the time that a reservation remains valid for and whether charging must start when the reservation is made or when the vehicle actually arrives at the parking location.

In some of our previous work [7], we classified a parking slot as a resource whose utilization and revenue must be maximized while increasing user satisfaction. This was achieved by applying a reservation mechanism for parking lots whose pricing varied with demand giving the users the option to choose between the most convenient or cost efficient options.

3) Mobile applications for parking

Numerous parking-related applications are nowadays available taking advantage of the processing, display and connectivity capabilities of modern mobile devices. The general trend followed is that parking space locations are displayed on a map allowing drivers to navigate to these locations. The level of information regarding each of these locations may vary from a simple indicator of its coordinates, to its vehicle capacity and hourly fees. Recently, a number of smart phone applications have become available that provide information about parking availability in real-time. Obviously, these applications rely on data received by an associated parking availability monitoring infrastructure as these were described above.

The applications are obviously of assistance to local drivers and visitors in an area. A real advantage is provided by those that report current availability and allow reservations. Their positive impact is immediate as they relieve drivers from searching for vacant spots. A common issue though, is that the applications are usually the result of an isolated initiative of a local authority or user group and as such they are targeting a specific geographical area; more generalized efforts are required in that respect.

B. Parking spaces for people with disabilities

A significant percentage of people suffer from temporary or permanent disabilities. They are issued with a special permit (called a ‘disabled badge’) that entitles the vehicle that they are driving, or are passengers of, to be parked at specially designated locations. These special parking spaces are often located close to shops, amenities and public administration offices enabling people with
disabilities to access them as easily as possible. According to current legislation, the disabled badge must be displayed on the windscreen; this enables visual verification of the vehicle’s entitlement to be parked at the designated spaces.

Under ideal circumstances, the existing scheme would operate adequately serving the people it is intended for. However, for a number of reasons there are many issues associated with the scheme which cause huge inconvenience for its legitimate users. First of all, the fact that the special parking spaces reserved for people with disabilities are located near places of interest and are sometimes empty, makes them an attractive parking location for opportunistic offenders. Additionally, parking at these spaces is usually free and the permit may also carry other concessions (e.g. access to central London without incurring the city’s congestion charge).

The convenience but more importantly the cost element, make the possession of a disabled badge quite attractive and as a result there are many offences carried out which include the use of forged and counterfeit permits or even the theft of permits for own use or resale. In some cases, valid permits may also be abused: the permit is displayed in the vehicle but the permit holder does not participate in the trip. To provide an idea of the extent of the problem, we note that in a recent report [8], the UK’s Audit Commission estimates that the amount of lost revenue from the abuse of the scheme is around 16 million pounds per year. The report also states that in the period between 2008 and 2011, around 50,000 permits were cancelled for a variety of reasons.

Monitoring the parking slots allocated to disabled badge holders is a difficult task for the authorities. A visual confirmation of the correct display of a valid permit is required something which is usually performed by parking attendants; as expected, the cost of accomplishing this is high and illegitimate users are not easily detected.

It is clear that any form of abuse of the scheme deprives those in genuine need of assistance from the special parking spaces. Moreover, although the permit is valid internationally, parking concessions vary between countries. As such, there are different rules as to where it is permitted to park and in some locations for how long one may do so (to enable fair usage); an automated method of conveying such information would be beneficial.

The locations of parking slots for disabled badge holders are often spread around in various areas. To assist people in finding them, a small number of specialized smart phone applications are available that indicate these locations on a map. Unfortunately, apart from a couple of exceptions that cover specific geographical areas, the information provided by these applications is static. In another note, as a form of reaction against illegitimate parking at disabled badge holder parking spaces, an application [9] has become available that enables citizens to report violations by taking a picture of the offending vehicle and sending it to the authorities for further action.

Based on all the above, the main question that arises is: how can an urban smart system properly and efficiently validate entitled users of disabled parking spaces on the spot? The utilisation of such a system (and perhaps its integration with existing systems that have a similar goal [10]) would in many cases alleviate the need for physical monitoring of the spaces as well as significantly reduce the response time to violations identified. Reducing abuse of the scheme would increase the availability of the parking spaces so that they are better utilized by their intended users. Defining the functionality of such a system and developing its components has been the focus of the work presented in this paper.

### III. THE DISASSIST SYSTEM ARCHITECTURE

With DisAssist we aim to provide a user friendly and flexible platform that allows people with disabilities to find available parking slots and verify themselves when they use one. Also, although the concept of parking reservation appears to be a challenge, we believe that it would be highly beneficial in the particular scenario we are examining; as such, we have incorporated it in our system.

The architecture of DisAssist is presented in Fig. 1. We observe that the system comprises of three major components: the server, a number of different clients and the underlying communication infrastructure.

The server will run a variety of services for data collection, data processing and data access. As such, it maintains up to date information on registered users as well as the parking spaces available to them. A diverse set of clients will provide the means through which end-users will interact with the system. We purposefully integrate a range of client solutions to enable users to select the most appropriate for their needs. Obviously the functionality will vary among clients; the most technologically advanced will naturally offer the most features. In Fig.1 we see how each client interacts with the system. More particularly we observe:

a) a mobile phone through which an SMS message is sent to indicate the parking slot the user has parked at.

b) an application running on a smart phone that is used to obtain parking location information as well as real-time availability information (where available). Moreover, the application will allow users to verify the parking slot they have parked at and perform a reservation for a slot.

c) a dedicated device that follows the IoT and M2M paradigms and communicates automatically with the rest of the infrastructure in order to authenticate the user and verify the parking slot occupied.

As expected, the various components of the system will take advantage of the existing communication infrastructure to exchange data. A crucial role is to be undertaken by a M2M communication gateway that is responsible for receiving the data from the various sensors and transmitting it to the server. This transmission will be carried out either through the existing cellular infrastructure or a wired connection. The cellular infrastructure is obviously used for the communication between end-user mobile devices and the server.
IV. SYSTEM IMPLEMENTATION

To allow us to demonstrate and evaluate DisAssist, we implemented its components and desired functionality.

A. System operation

In brief, the system has four distinct operation phases: data collection, data dissemination, reservation management and user verification.

Data collection is achieved by sensors located at the parking slots that detect the presence of a vehicle. Data gathered is disseminated to the users in the form of real-time parking slot availability information. Reservation management handles all the reservation requests and monitors currently active reservations in order to detect no-shows. Finally, upon arrival of a user at a parking slot, verification must take place in order to confirm that the user is a disabled badge holder.

The user has the ability to interact with the system through a number of different methods which as we will see later, offer different functionality. The only obligatory action is the user verification as it enables the system to confirm the appropriate usage of the parking slots. Upon departure from a parking slot, there is no form of action required by the user; the system readily detects this through the vehicle detection sensor which as soon as the vehicle leaves will report the slot as empty.

B. Server Implementation

The server implements the various gateways via which the clients and sensors interact with the central system services. The distinct ‘users’ and ‘parking spaces’ databases contain all the information that the system requires in its operation. Such information includes user details and the current status of the various parking slots as well as the current reservations and detected violations. The implementation of the database service is based on MySql and client interactions are enabled through Glassfish and JSON. The incoming SMS messages are received and processed by a specially developed program.

C. Field equipment

As briefly mentioned, the infrastructure of DisAssist includes IoT-related hardware components. More specifically, each parking slot is equipped with a magnetic sensor in order to detect the presence of a vehicle. As highly frequent readings are not required in our specific application, the detection interval is set to 20 seconds; to ignore any intermittent detections (e.g. vehicle passing over the space), the presence of a vehicle is signalled once two consecutive positive readings are detected; a similar logic applies when a vehicle departs.

Accompanying the magnetic sensor is an XBee module that is responsible for transmitting the sensor’s readings to the gateway using the 868 MHz frequency. This occurs whenever a change of status is detected (i.e. a vehicle has arrived or has departed) as well as at regular intervals to
verify correct operational status. The gateway forwards the
data to the server via an ethernet cable connection.

Finally, at each parking slot there is an indicator (in the
form of an LED) that provides a colour-based
representation of the status of the slot in four modes:
• red: the slot has been reserved
• blinking red: slot occupied by unauthorized vehicle
• green: the slot is available
• blinking green: blinks occasionally to indicate
  authorized usage and to verify its correct operation

D. Client equipment

As mentioned, a user can interact with the system in a
number of ways and through different equipment. The
simplest client comes in the form of a mobile phone that is
used to send a text message to the service; the content of
the message is simply the parking slot ID that the user has
parked at. More advanced solutions come in the form of a
smart phone client and a dedicated device:

1) Smart phone client

Offering extensive functionality, the smart phone client
(which was developed for devices running the Android
operating system) allows the user to interact with the
system in real time. In the three figures below, we observe
the operation of the client. More precisely, in Fig.2 the
application displays the current availability at the parking
locations in the area. To conserve bandwidth, availability
data is only requested for the locations currently displayed.

We observe that three out of the five parking lots have
slots available and the system can inform users of the
parking policies applicable at the various locations. At this
point, the user can elect to drive towards one of these
parking lots. However, continuous monitoring is required
since at any time the desired (and currently available) slots
may become occupied; in that case, a change of
destination will be necessary.

Alternatively, once availability at a parking lot is
observed, the user can submit a request to reserve one of
the currently available slots. The system then confirms the
reservation and returns the details of the particular parking
slot that has been reserved (Fig. 3). To ensure fair usage of
the slots, a user can only have one active reservation at a
time. Moreover, an active reservation will be cancelled
automatically if the user does not arrive at the reserved
parking slot within a time period which is based on the
user’s distance from the slot; to prevent underutilization of
the spaces, the grace period can not exceed 15 minutes.

Finally, upon arrival the user has to confirm that he/she
has parked at the right slot (Slot 77 in this instance, as
shown in Fig. 4) so that the system can update its status
from ‘Reserved’ to ‘Occupied’. The small list of slots
displayed consists of those slots that are within a few
meters (to account for GPS inaccuracies) of the user’s
location as obtained by the smart phone’s GPS receiver.
Note that even if the user does not make a reservation, the slot confirmation function will still be available as slot confirmation is always necessary. Based on Fig.4, any legitimate user could come and park at slot 78 or 79 and carry out the location confirmation function; confirmation results in the status of the slot turning to “Occupied”.

2) The DisAssist device

The user interactions with the system were so far based on mobile communication technologies. To fully integrate IoT in our implementation, we used off-the-shelf components to develop the DisAssist device; its purpose is to streamline the user verification process even further. The DisAssist device comprises of a battery powered compatible microcontroller equipped with an XBee module. The device is programmed to send the user’s ID when it gets the chance to join the DisAssist network. Verification takes place based on the user ID as well as the XBee module’s MAC address. All the user has to do is switch on the device and wait for the led attached to turn green (indicating that the user has been verified); at this point the device can be switched off.

E. User and location verification

One of the most novel aspects of DisAssist is the ability to verify a user through a variety of means. Even though DisAssist is based upon advanced technology, it also caters for standard mobile phone users; provided that a user has registered his/her mobile phone number, the system performs user verification via a simple text message that contains the parking slot ID. The smart phone application and the DisAssist device transmit the user ID automatically. Upon user verification, the system marks the given parking slot as legitimately occupied. Obviously, if no user and slot verification information is received after a reasonable period of time (set to 3 minutes) the system eventually marks the slot as violated; parking slot violations are handled by the authorities.

It is obvious that the user verification methods are much more secure than the simple display of the disabled badge and are a means of reducing abuse of the scheme. This somehow relies on the basis that the scheme’s legitimate users do not perform any unethical actions themselves. Finally, the continuous updating of the status of the various parking slots makes monitoring much more efficient and helps the authorities to carry out law enforcement as well as policy adherence in a more radical manner. Moreover, statistical information on parking slot usage will surely aid in future planning.

It is important to note that no unnecessary information is gathered or stored by the system in order to protect the privacy of its users. As such, parking administrators monitoring the ‘parking spaces’ database have access to the status of each slot but not to the identity of the user that was verified upon arrival based on data from the ‘users’ database.

V. CONCLUSIONS

The Internet of Things is becoming applicable in an increasing number of people’s daily activities. In this paper, we described the architecture and implementation of the DisAssist system. DisAssist is based upon the integration of sensor technologies with wireless and mobile communications. It provides a diverse set of functionalities aiming primarily to assist people with disabilities to utilise parking spaces reserved for their use efficiently and hence carry out their activities with ease. Through the fully transparent verification mechanisms offered by DisAssist, the overall security of the scheme is improved making it less prone to abuse. Future work will entail various improvements to the system concentrating on reservation enforcement which will enable for reservations to be made for future time periods.

REFERENCES